N91-16926

PROPERTIES OF THE REDSHIFT

W. G. Tifft, W. J. Cocke
Steward Observatory, Univ. of Arizona

Introduction

Central to any analysis of dynamical systems, or large scale motion, is the interpretation of redshifts of galaxies as classical Doppler velocity shifts. This is a testable assumption and for many years evidence has accumulated that is inconsistent with the assumption. Here we review recent evidence suggesting systematic radial dependence and temporal variation of redshifts.

Background

Early 1970s Redshift-Morphology and Redshift-Magnitude, ApJ **188**,221 (1974)
1973-4 Quantized redshift concept introduced, IAU Symp 58 (1973)
1976-7 Formal predictions, general discussion, ApJ **206**,38 (1976),**211**,31 and 377 (1977)
Mid 70s to mid 80s Double galaxy programs - ApJ **336**,128 (1989)
Early 80s Global quantization, ApJ **287**, 492 (1984), Croasdale ApJ **345**,72 (1989)
Mid 80s New precision 21-cm programs begun, ApJ Suppl **67**,1 (1988)
Mid 80s Early theoretical concepts, Astroph Lett **23**,239 (1983), ApJ **288**,22 (1985)
1987 Time variation concept introduced, Venice Symposium (1987)
Lyman Alpha forest quantization, q_o, ApJ **346**,613 (1989)
1987-88 21-cm multiple radio telescope investigations A&A Suppl (1990), ApJ Suppl (1990)

For summary up to 1988 see AAS Poster paper June 1988. Copies are available on request.

21 cm PROFILE PARAMETERS

V = Mean of redshift at 20% of average height of central 80% of profile area. Determined by polynomial fits to profile wings.

W = Profile Width, redshift difference across profile, 20% level.

F = Flux, Profile integral, converted to Jansky km/s units, with no corrections for beam size.

A = Profile shape or asymmetry index, ratio of velocity intervals from the mean redshift by AREA to the 20% profile crossing points. Taken as larger/smaller. + if larger interval on high redshift side, left leaning, − if larger interval on low redshift side, right leaning.

S/N = Signal-to-noise level, Ratio of average height of central 80% of profile area to rms baseline noise.

UNCERTAINTY IN 21 cm DATA

The *consistency* of a parameter measures the ability to reproduce a quantity. By changing specific factors the effects of the factors on consistency can be evaluated. Two critical factors we will consider later are radial scale (beam size), and the epoch of observation.

The *accuracy* with which a measurement represents some specific physical quantity, is much more difficult to obtain. Whether a physical quantity is stable or changes in some parameter dependent way can, however, be determined within the limits of consistent measurements.

Using a set of 100 system standards, observations were obtained at the Effelsberg 100-meter and the NRAO 140- and 300-foot telescopes within a one year span, 1987-88. At S/N of 10 or above comparisons show a redshift scatter, σ_V, with a simple bandwidth dependence.

PRECEDING PAGE BLANK NOT FILMED

$$\sigma_V = 0.85(BW/BW_5)^{1/2}\ km/s,$$

BW is the bandwidth in MHz and is 10, 5, 2.5, or 1.25 at NRAO. The rms reproducibility of a single measurement at S/N 10 or above is therefore 1.2, 0.85, 0.6, or 0.4 km/s at the respective bandwidths. See Tifft and Huchtmeier A&A Suppl (1990), Tifft ApJ Suppl (1990).

Uncertainty in widths is twice that in redshift. Aside from some obvious telescope system or software errors no systematic errors were detectable. Comparisons at the level of a fraction of a km/s are possible.

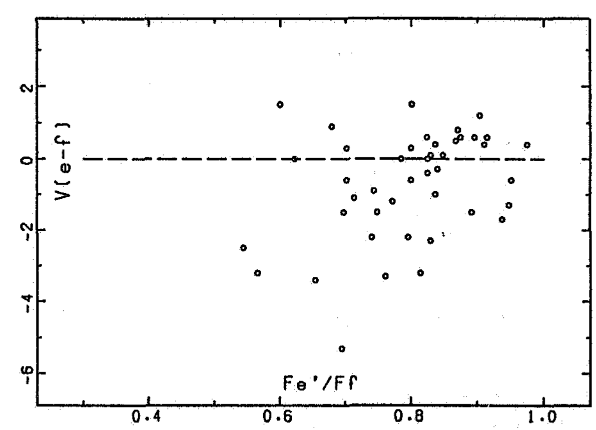
Absolute flux calibrations and comparisons between different telescopes permit flux growth curves to be measured as a function of beam size. This allows one to compare derived parameters as a function of radius. Comparisons of flux measures since 1984 at the 300-foot show an overall stability within about 2%, but show a systematic difference of a few percent in the long term behavior of fluxes for wide and narrow profiles. The behavior changes quite sharply at a width of 100 km/s.

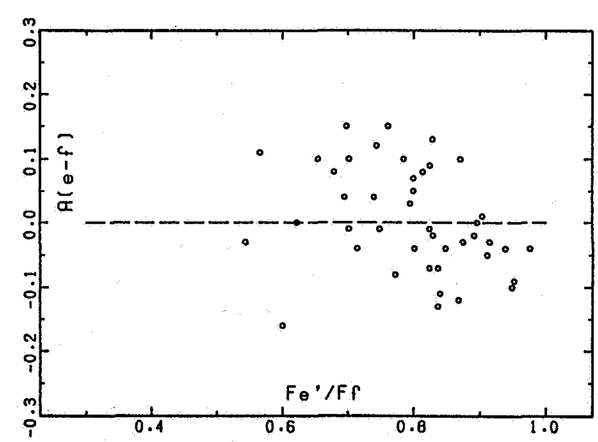
RADIAL DEPENDENCE OF PROFILE PARAMETERS

The flux ratio between two telescopes provides a direct measurement of the degree to which the larger beam samples outlying hydrogen not seen by the smaller beam. Systematic deviations in any of the parameters of the 21 cm line as a function of radius should be apparent when plotted against flux ratio. The effect is readily seen for profile width when the 9 arc minute beam of the 100-m telescope is compared with the 21 arc minute beam of the 140-ft. When comparing galaxies at different distances, as in the Fisher-Tully method, slight systematic errors will occur unless beam size corrections are applied.

More surprisingly the comparison of redshift change with flux ratio appears to show that the redshift of the central parts of galaxies with disks (W > 100 km/s) are systematically blueshifted. The effect is opposite or absent for narrow profile galaxies. The effect changes at the same width that the long term flux behavior of the 300-ft data changes. At this width the standard double horned profiles associated with rotating disks have replaced the single peaked profiles characteristic of dwarf irregulars.

The effect implies that the central regions of a galaxy should have a systematically positive shape index relative to the outer parts. The comparison of the 100-m and 140-ft shape index A shows the expected trend with flux ratio. If the neutral hydrogen content of galaxies is optically thin, as is normally assumed, radial expansion cannot explain the shift. The redshift change can amount to several km/s when only 20-30% of the hydrogen lies outside the smaller beam.





Radial variation in redshift (left) and profile shape (right) within galaxies. The redshift or asymmetry difference (100-m − 140-ft)=(9′− 21′ beam) is shown as a function of the flux ratio for individual galaxies with profile widths W > 100 km/s. Redshift becomes more negative toward the nucleus and profiles show an enhancement on the negative side at small radii.

REVIEW OF GLOBAL QUANTIZATION

Although quantization of redshifts on a global scale was implied by very early redshift work in the 70s, it was not until the early 80s that the Fisher-Tully study of dwarf galaxies permitted a clear solution for the solar motion. Correction for a velocity (circular, radial, z) = (231, −35, 1) produced strong global quantization at 24.15 km/s among dwarf galaxies with the narrowest profiles (W < 75 km/s). A separate test for the widest profile galaxies yielded a global periodicity of 36.2 km/s for the same solar motion. Recently M. Croasdale (ApJ **345** (1989)) has independently demonstrated the wide profile periodicity in independent data. Both periods are simple fractions of the 72.45 km/s interval associated with quantization in dynamical systems. Recently (ApJ **346** (1989)) the concept of global quantization has been applied to Lyman alpha forest data in quasars which carries with it a potential for determining q_o.

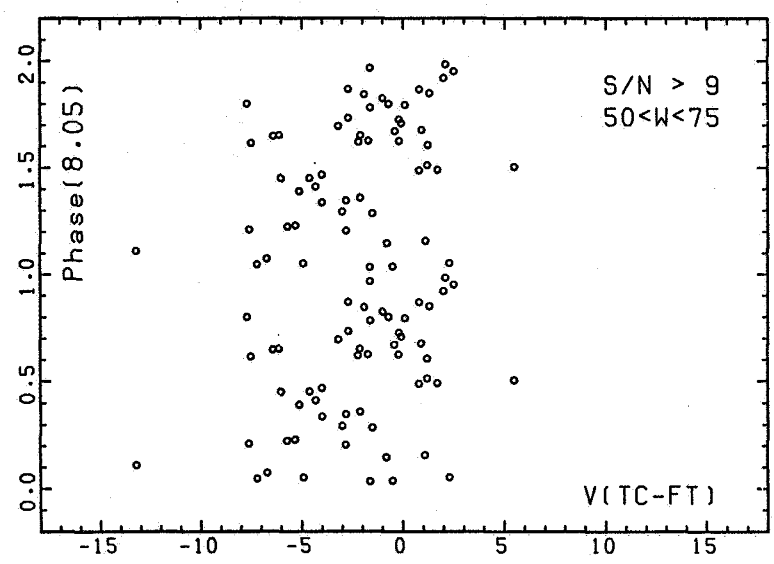
Redshift phase, ϕ_V, is defined as the fractional part of the galactocentric redshift, V_c, after divison by the quantum interval or period, P.

$$V_c/P = N + \phi_V.$$

Quantization is generally evaluated by comparing the number of galaxies which are in phase with a period with those out of phase. The resultant In/Out or Head/Tail ratio is evaluated statistically according to simple coin toss probability theory or more sophisticated Monte Carlo simulations depending upon the degree to which the phase intervals can be predicted in advance. A study of redshift phase dependence is crucial to the discussion of redshift time variability. Systematic errors will shift all phases in a nonselective manner. What is observed is that shifts appear to occur over time in specific phase intervals.

TIME VARIABILITY OF REDSHIFT

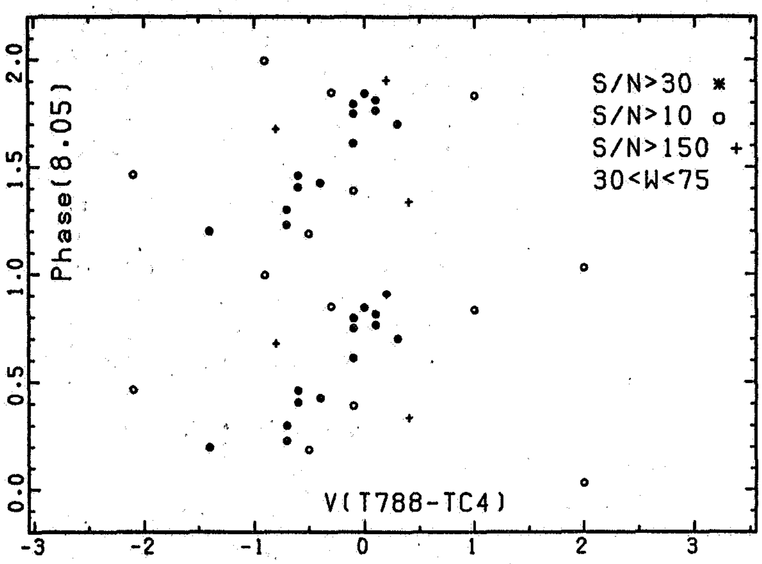
Comparisons of the accurate redshifts derived by Tifft and Cocke (TC) in the mid 80s with older redshifts generally show a scewed distribution toward negative values of V(new − old). When residuals are plotted against redshift phase deviant residuals cluster in phase. This effect was first seen in narrow profile data.



Original 1987 demonstration that Fisher-Tully redshifts from the 70s differ from new redshifts in the 80s in a phase dependent way. The implication is that redshifts near phase 0.25 are decreasing with time while those near phase 0.75 are stable. Phase is calculated on a global period of 8.05 km/s for narrow profile dwarf galaxies.

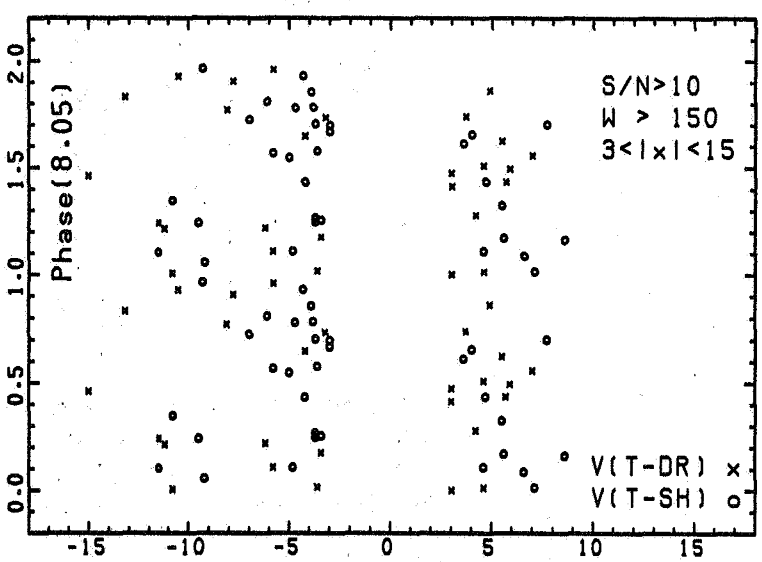
The characteristic 24.15 km/s periodicity associated with W < 75 km/s is apparently a modulation of a more fundamental period of 8.05 km/s. On an 8.05 period the narrow profile points near phase 0.75 show no shift when Fisher-Tully (FT) redshifts are compared with TC data. At phase 0.25 a shift of 4-5 km/s is observed. This effect was formally announced at the Venice Symposium on New Ideas in Astronomy held in 1987. In 1988 a set of the narrow line galaxies was reobserved and compared against the principal run of January 1986 from the TC study. The 0.75 phase group is at zero while the 0.25 phase group is again

shifted. Uncertainty in the new data is well understood, and consistent with the observed scatter. A formal t test comparison of the means of the two phase groups gives t=4.9, p<0.001, that the 13 high S/N points have the same mean. Including three very bright resolved systems and lower S/N data lowers the probability of coincidence to about 0.01. The magnitudes of the shifts are, within their uncertainties, proportional to the time intervals between data sets. The shifts require rates of change of several tenths of a km/s per year.



Current test of the variation of redshift for dwarf galaxies with narrow line profiles. Precison redshifts obtained in 1988 and 1986 show that galaxies near phase 0.25, for the basic 8.05 km/s period, continued to shift by an amount proportional to the time interval between observations.

To provide further tests for time change, and to establish a basis for further predictions, overlap was extended to compare redshifts with several other 300-ft investigations done in the mid 70s. This included work by Dickel and Rood (DR) and Shostak (SH). These studies tend toward more luminous wider profile galaxies than the Fisher-Tully program. However, both studies indicate the presence of an underlying 8.05 km/s periodicity, especially for W < 150 km/s and the larger residuals for wide profile data (W > 150 km/s). Without the distinction provided by the time differentials the periodicity would be essentially undetectable. Flux level and profile shape also appear to provide or sharpen sample discrimination in certain cases.



Demonstration that the basic 8.05 km/s periodicity extends to wide profile data and shows phase dependent shifts. Redshifts from the 70s by Dickel and Rood (DR) and Shostak (SH) are compared with new precision redshifts from the 80s.

HIGHER ORDER PERIODICITIES

With the advent of time differential comparisons it has become increasingly likely that most of the periodicities seen are modulations of an underlying 8.05 km/s interval. This appears especially to be the case for

the narrow profile 24.15 km/s periodicity. The 24.15 km/s period in turn shows a population modulation over a triple 72.45 km/s period. It is now apparent that the fourth multiple of 8.05 = 32.2 km/s modulates major portions of wide profile data when time differentials are invoked.

The DR and SH time base comparisons are modulated at 32.2 km/s for differentials near zero on profile wider than 150 km/s. Deviations near phase 0.5, based upon P=32.2, show negative V(new − old) residuals. Near phase 0.2 residuals are positive. Still larger positive residuals fit the periodicity at phase 0.8-0.9. Portions of the residual range, especially the larger negative residuals, fit a 24.15 km/s modulation. Preliminary internal comparisons within the newest redshift data are consistent; however, the time baseline is still too short to provide significant separations. The basis now exists, however, to make specific predictions.

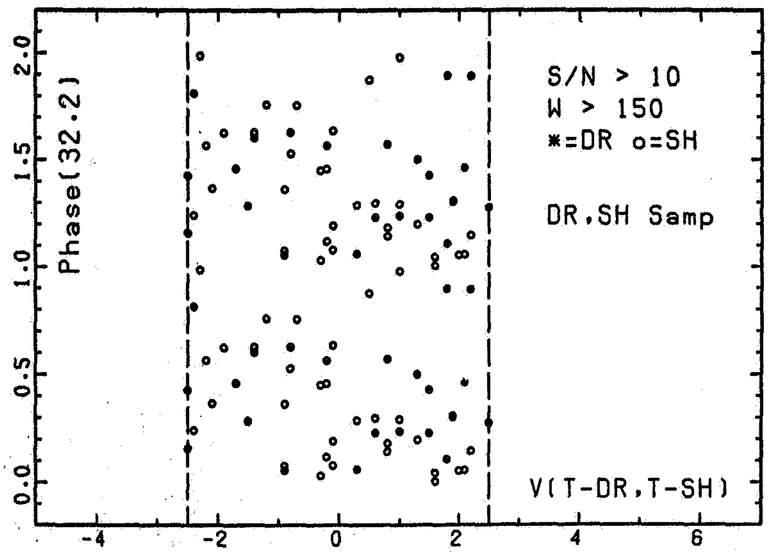


Illustration that the underlying 8.05 km/s periodicity for wide profile galaxies is modulated at 4 times 8.05 or 32.2 km/s for galaxies showing only small redshift differences over time. Future testing of the time variation of redshifts will be based upon confirming and mapping such changes.

The presence of certain multiples of 8.05 in preference to others suggests that a higher regularity may exist. There is some suggestion that higher multiples of the 8.05 km/s period relate to increasing width in a regular pattern. It will require longer time baselines and extended samples to seriously investigate such questions.

THEORETICAL DEVELOPMENTS

A self-consistent nonrelativistic theory of redshift quantization has been published (Astroph Lett **23**, ApJ **288**). These references established a quantum theory which represented the nonrelativistic redshift as a differential operator. The eigenvalues of this operator are quantized in an appropriate way if galaxies are fermions. The theory showed that, if the basic quantization interval $c\Delta z$ is 12 km/s, the Planck's constant for this sort of quantum mechanics is $\hbar \approx 2.4 \times 10^{73}$ erg s. A more basic quantity, however, is the analog of the Compton wavelength, $\mu = (\Delta z)^2/2H_0$. If $H_0 \approx 90$ km/s, then $\mu \approx 8 \times 10^{18}$ cm ≈ 3 pc.

An interesting feature of this theory is that the gravitational analogue of the Bohr radius, $\hbar^2/me^2 \rightarrow \mu^2c^2/GM$, turns out to be ≈ 3 kpc, for $M \approx 5 \times 10^{10} M_\odot$. Thus a galaxy might consist of two or more gravitationally bound fermions.

We propose a relativistic extension of this theory in which the fermions are governed by the Dirac equation in a Riemannian space-time. The background metric would be the usual Robertson-Walker metric. Nonrelativistic quantum mechanics would not predict observable changes in galaxy redshifts in anyone's lifetime. In relativistic QM, however, there is the phenomenon of 'jitter' (Ger. *Zitterbewegung*) with a time scale of $\hbar/m_ec^2 \approx 10^{-21}$ sec. This is the time that it takes light to cross the Compton wavelength. In our theory, this becomes $\mu/c \approx 3 \times 10^8$ sec ≈ 10 years. This time scale is roughly consistent with changes that have already been observed.